Forest Fire Danger Projections in the Mediterranean using ENSEMBLES Regional Climate Change Scenarios

Supplementary Material

1 Method

1.1 Description of the Fire Weather Index System

The Canadian Forest Fire Weather Index (FWI System) constitutes a building block of the Canadian Forest Fire Danger Rating System (CFFDRS) established in Canada since the early 70's (van Wagner, 1987; Stocks et al, 1989) and subsequently adopted in other regions of the world, such as the Mediterranean (Viegas et al, 1999; Dimitrakopoulos et al, 2011), Indonesia and Malaysia (deGroot et al, 2006) or New Zealand (Briggs et al, 2005), among others.

The Fire Weather Index (FWI) System consists of six components rating the effects of fuel moisture content and wind on a daily basis, based on various factors related to potential fire behaviour (Fig. 1). The first three components, referred to as the Fine Fuel Moisture Code (FFMC), the Duff Moisture Code (DMC) and the Drought Code (DC), rate the average moisture content of different soil layers, respectively fine surface litter, decomposing litter, and organic layers. Wind effects are then added to FFMC to form the Initial Spread Index (ISI), which is an indicator of the rate of fire spread. The remaining two fuel moisture codes (DMC and DC) are combined to produce the Build Up Index (BUI), which rates the total amount of fuel available for combustion. BUI is finally combined with ISI to produce the Fire Weather Index (FWI), a dimensionless index rating the potential fire line intensity given the meteorological conditions in a reference fuel type (mature pine stands) and level terrain. The Daily Severity Rating (DSR, van Wagner, 1970) is calculated as an exponential function of FWI, used to better reflect the expected efforts required for fire suppression. Moreover, DSR was specifically designed to be averaged either in time (e.g. seasonally, leading to the seasonal severity rating, SSR) or in space in order to characterize the average fire danger conditions over certain areas/regions. The FWI System uses as input four meteorological variables: daily accumulated precipitation and instantaneous wind speed, relative humidity and temperature. According to the standard data recording protocol, these variables should be measured at noon local standard time (Lawson and Armitage, 2008).

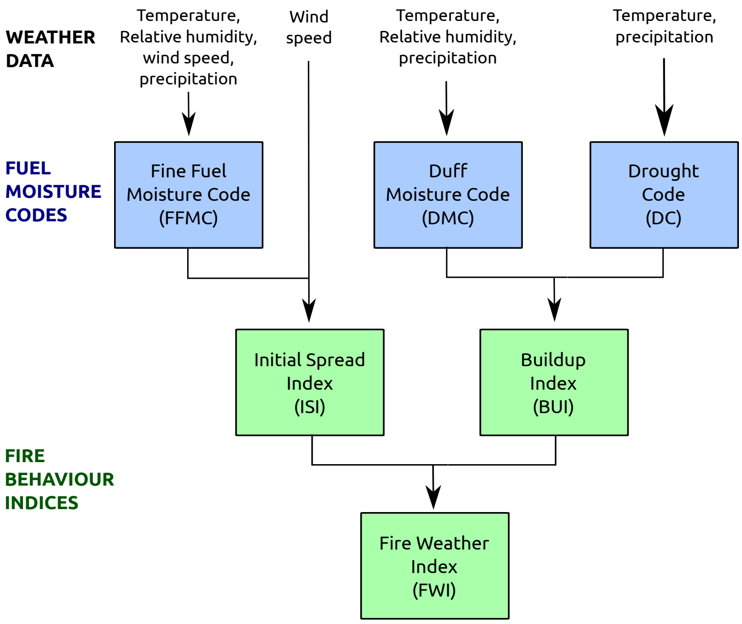

Figure 1: Block diagram of the CFFWIS (Adapted from van Wagner, 1987)

1.2 Regional climate change scenarios from RCMs

In Table 1 a summary of the RCMs used in this study is provided.

Table 1: Summary of the ENSEMBLES RCM simulations used in the study. Throughout the text, the different RCM-GCM couplings are named using the acronyms indicated in the first column, which correspond to the modelling centres/institutions.

Acronym	RCM	GCM	Reference
C4I	RCA3.0	HADCM3-Q16	Kjellström et al (2005)
ETHZ	CLM	HADCM3-Q0	Jaeger et al (2008)
HC	HadRM3	HADCM3-Q0	Collins et al (2006)
KNMI	RACMO	ECHAM5-r3	van Meijgaard et al (2008)
MPI	M-REMO	ECHAM5-r3	Jacob et al (2001)
SMHI	RCA3.0	ECHAM5-r3	Kjellström et al (2005)

1.3 Observational reference dataset assessment

The Water and Global Change EU-funded project WATCH (2007-2011, `www.eu-watch.org`) originally provided a gridded observational dataset based on the ERA-40 reanalysis and observational data, known as the WATCH Forcing Dataset (WFD), and encompassing the period 1901–2001. Following the same methodology (described in Weedon et al, 2011) and building upon the more recent ERA-Interim reanalysis (Dee et al, 2011), the WFDEI dataset was recently released for public use. The WFDEI dataset consists of eight meteorological variables at 3-hourly time steps and as daily averages, for the global land surface at 0.5° resolution for the period 1979–2012. It has been chosen for application in this study because it allows the calculation of FWI according to its original definition and to the different proxy versions tested in this study as far as both instantaneous and daily mean values are available, and also because of the better adequacy of ERA-Interim for fire danger applications compared to ERA-40 (Bedia et al, 2012). In addition, we tested both WFD and WFDEI and the spatial correlations attained in the case of WFD were lower, and it exhibited a much higher negative bias, requiring a significantly higher rescaling factor to match the RCM ensemble mean (1.42) as compared to WFDEI (1.17). The added value of using WFDEI compensates for the different time spans (1979-2000 *vs.* 1971-2000), which has a negligible influence in climatological terms. Temperature, wind and precipitation were directly retrieved from the WFDEI database, whereas relative humidity was calculated from temperature, mean sea level pressure and specific humidity values.

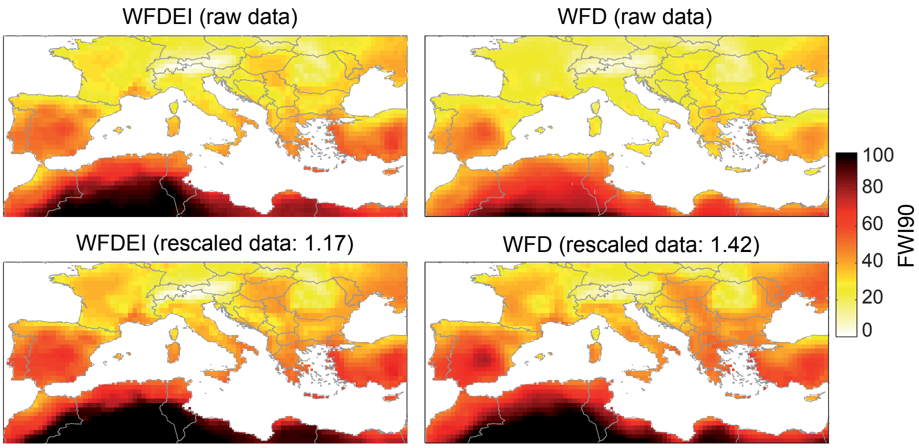

Figure 2: Comparison of the WATCH Forcing Dataset based on ERA-40 (WFD) and the WATCH Forcing Dataset based on ERA-Interim, for the FWI90 indicator, calculated using the original definition of the index (instantaneous values at 12 UTC –version C0–). The two upper panels display the original values. The two lower panels have been rescaled to match the multi-model ensemble mean in order to highlight the differences in the representation of the spatial pattern of fire danger. The rescaling factor is indicated in parenthesis, revealing the negative bias of WFD with respect to WFDEI.

2 Results

2.1 Best proxy selection for FWI calculation

The inter-comparison of proxies for the FWI System components (spatially averaged for the same period) are shown in Table 2. Note that DC does not depend on relative humidity, but only on precipitation and temperature (see

Wotton, 2009, for a detailed review of FWI System components) and therefore, the pairs C2-C4 and C1-C3 show identical results for this component.

Table 2: Spatial mean, 90-th percentile and correlation (Spearman's *rho*) of the different FWI System components with respect to the reference FWI System (C0, Table 1 of the manuscript), according to the different input proxy combinations, considering the mean values of the period 1971-2000 (20C3M scenario). Boldface highlights the closest value to C0.

	*C0**	*C1*	*C2*	*C3*	*C4*
Mean					
FFMC	84.9	78.8	80.8	**85.5**	87.3
DMC	130.1	82.1	105.0	**121.0**	153.3
DC	560.5	482.0	**594.2**	482.0	**594.2**
ISI	6.9	3.8	4.6	**7.2**	8.7
BUI	153.9	106.6	134.6	**140.1**	176.2
FWI	26.2	16.2	19.1	**26.9**	31.1
DSR	11.0	5.1	6.7	**11.6**	14.6
90-th percentile					
FFMC	93.2	89.0	90.4	**93.5**	94.8
DMC	269.9	170.8	220.3	**248.8**	319.6
DC	883.7	770.6	**932.1**	770.6	**932.1**
ISI	11.9	6.6	7.9	**12.1**	14.3
BUI	291.0	205.0	258.8	**264.7**	335.7
FWI	42.0	27.5	31.8	**42.3**	47.8
DSR	21.1	10.3	13.2	**21.5**	26.5
Spearman's ρ					
FFMC	–	0.96	0.97	0.97	0.97
DMC	–	0.99	1.00	1.00	1.00
DC	–	1.00	1.00	1.00	1.00
ISI	–	0.93	0.94	0.94	0.94
BUI	–	0.99	1.00	1.00	1.00
FWI	–	0.89	0.92	0.93	0.93
DSR	–	0.89	0.92	0.93	0.93

2.2 Analysis of FWI Projections in Present Climate Conditions

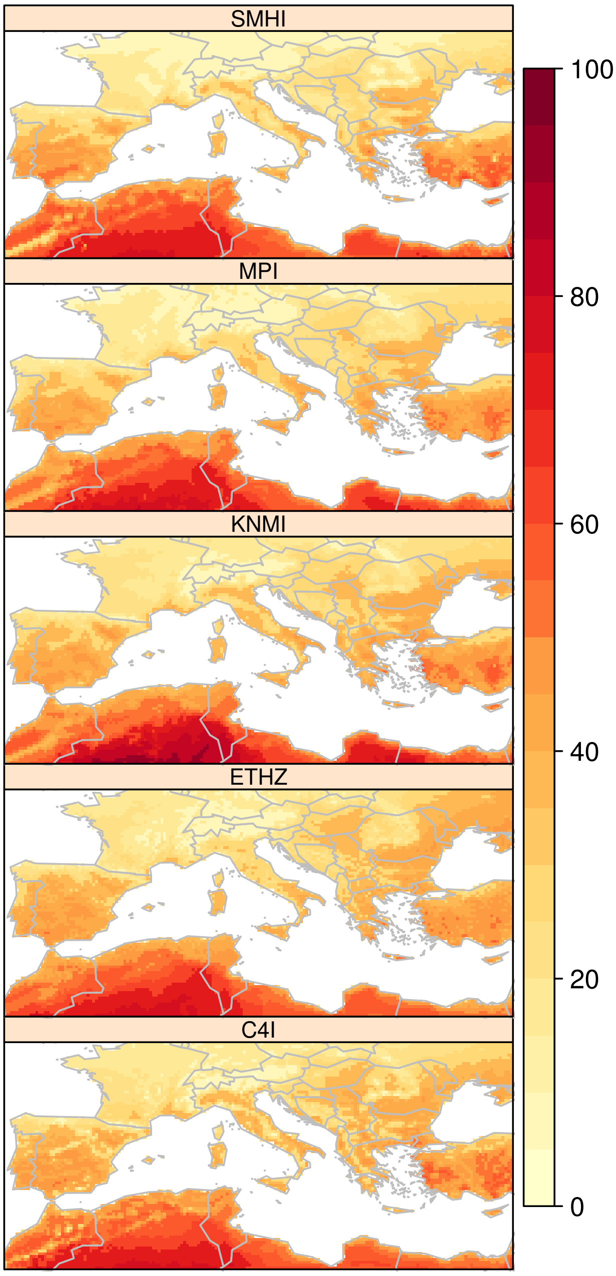

Figure 3: FWI control run scenarios (1971-2000) according to the five RCMs used in the multi-model ensemble for the fire danger season (JJAS).

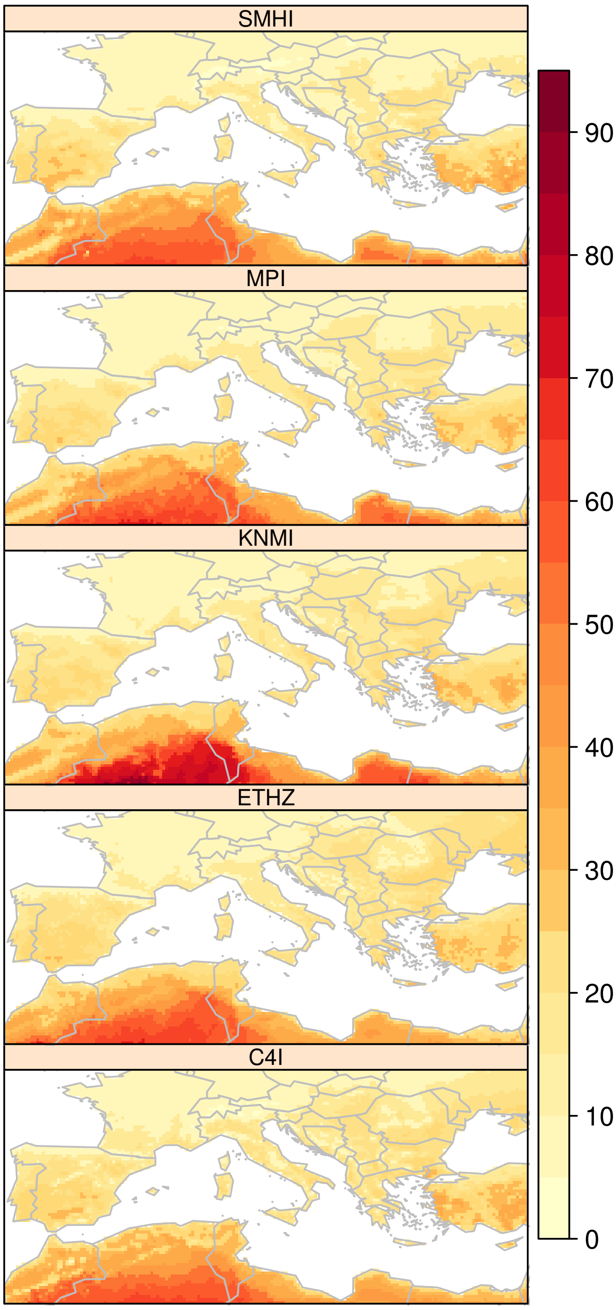

Figure 4: Same as Fig. 3 for SSR.

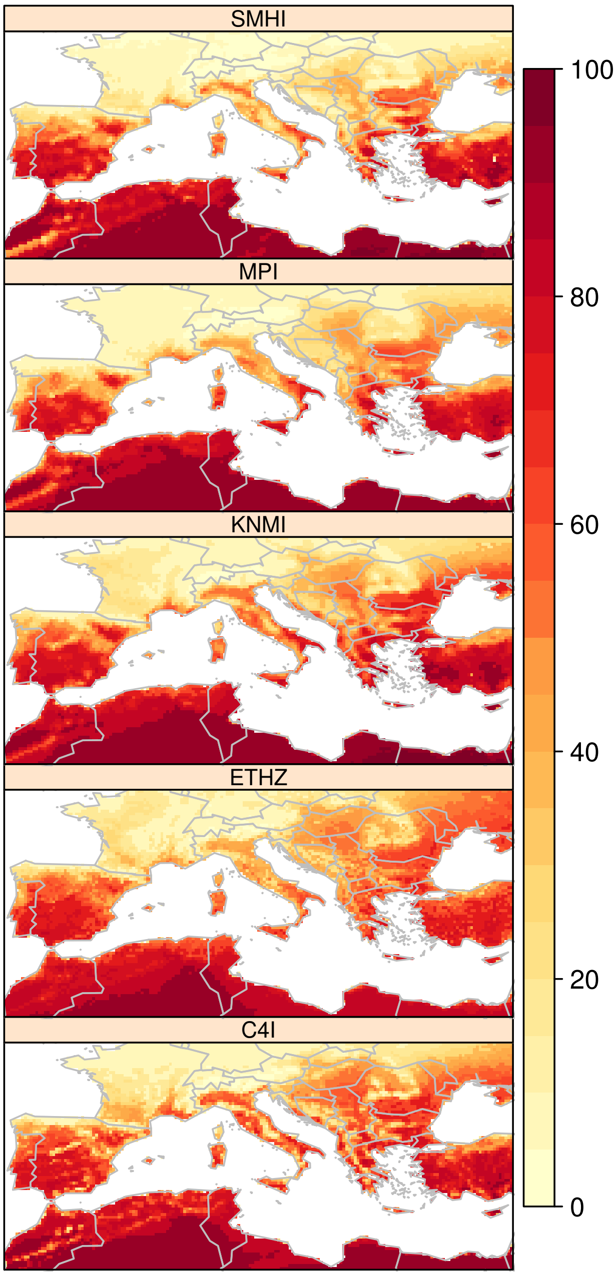

Figure 5: Same as Fig. 3 for FOT30.

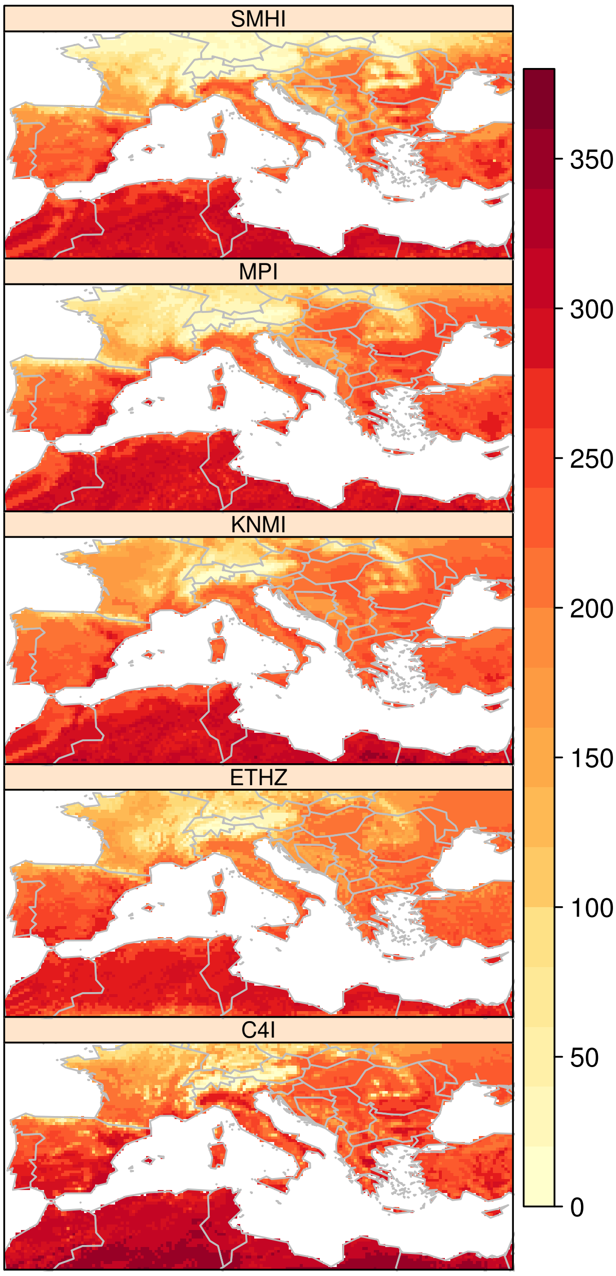

Figure 6: Same as Fig. 3 for LOFS.

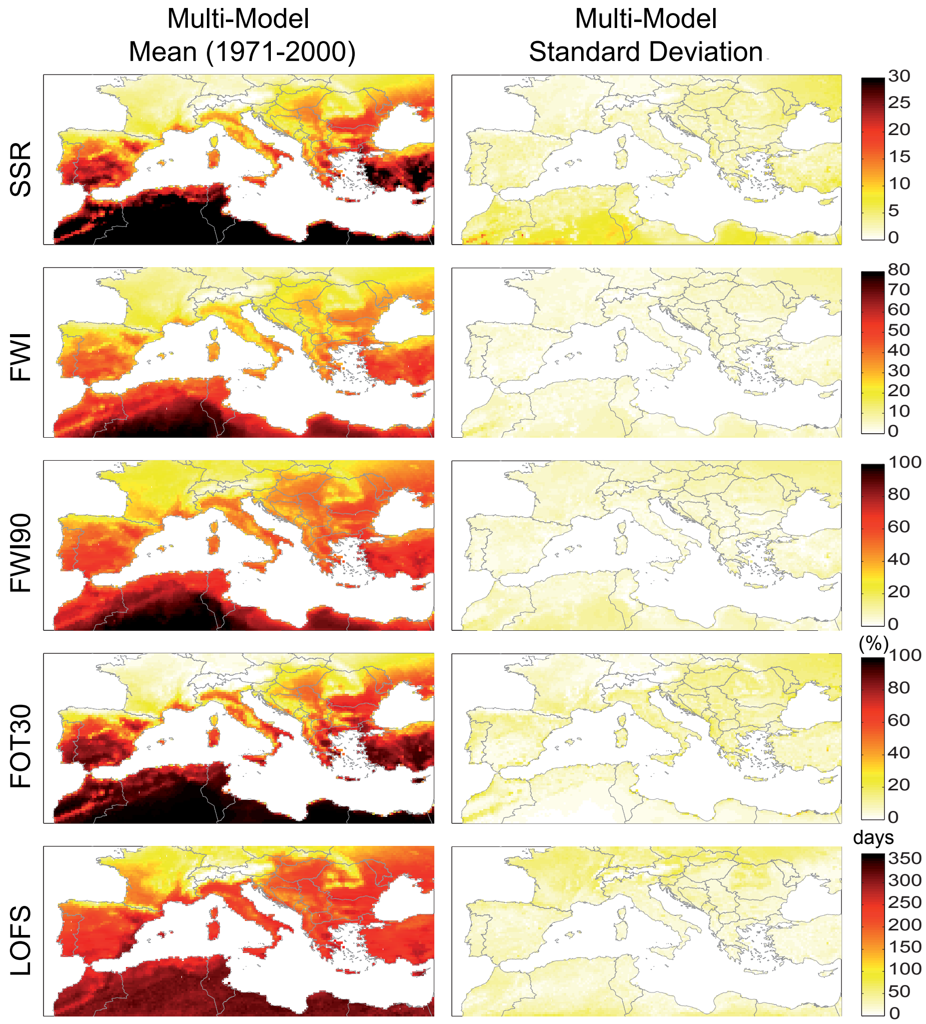

Figure 7: Mean (Left) and standard deviation (Right) of the multi-model ensemble projections of the fire danger indices (SSR, FWI, FWI90 and FOT30) and LOFS according to the 20C3M scenario (1971-2000).

2.3 Future FWI Projections

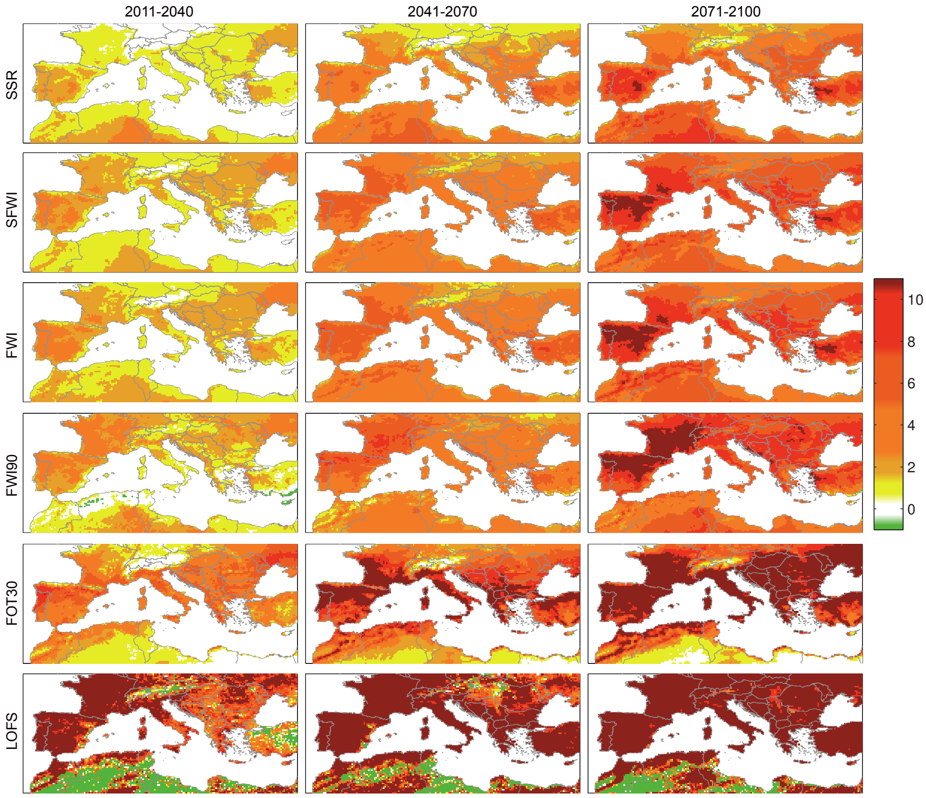

Figure 8: Mean relative deltas, in % with respect to the control run (1971-2000), of the different FWI-derived fire danger indices used in this study, for three time slices of the transient period (2011-2040, 2041-2070 and 2071-2100).

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